ON THE SO-CALLED "POSTGLACIAL FORMATIONS" OF SCOTLAND

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The purpose of this paper is to pass in review the several geographical and climatic changes which followed on the disappearance of the last very considerable snow-fields and glaciers from the Scottish mountains. Three well-marked stages in the glaciation of our country are readily recognized. The earliest of these is represented by the widespread ground-moraine long known here as our "Lower Bowlder Clay." This deposit was laid down during the epoch of maximum glaciation, when the whole country—mainland and islands alike—lay buried underneath one vast ice-sheet, which extended south as far as the valley of the Thames. The succeeding stage is evidenced by our "Upper Bowlder Clay"—a deposit of the same general character and origin as the lower ground-moraine. The ice-sheet underneath which it accumulated, however, did not flow so far southward as its predecessor. It seems, indeed, to have barely reached the midlands of England. Nevertheless, Scotland was as broadly covered by this ice-sheet as by that of the earlier epoch. The next stage of glaciation was marked by the presence of district ice-sheets and large valley-glaciers in our Highlands and Southern Uplands, and by less imposing snow-fields and glaciers in the mountainous parts of England, Wales, and Ireland. This stage is represented by local accumulations of bowlder-clay, terminal moraines, and sheets of torrential gravels.

There has always been considerable doubt among geologists as to where we should draw the line between glacial and postglacial deposits. Nor is this strange when we reflect that glacial conditions must have lingered longer in some regions than in others. The valley moraines of the Scottish Highlands, for example, belong to a much later stage than the "chalky bowlder-clay" of the Thames

[1] The substance of a lecture given to the Scottish Natural History Society, June 7, 1906.

valley. The deposits overlying that bowlder-clay have nevertheless been classified as *postglacial*, although it is obvious that they must be of much greater antiquity than the alluvia and peat resting upon the valley moraines and fluvio-glacial accumulations of our district ice-sheets in Scotland. The fact is, the term "postglacial" is quite misleading, and ought never to appear in any general classification of formations.

Continued research in Europe, America, and Asia has demonstrated that the so-called Ice Age was not one long uninterrupted period of glacial conditions, but an extensive cycle of alternating cold and genial conditions, which commenced before the close of Pliocene times and endured down to the very dawn of the present. I believe, therefore, that the upper members of the Pliocene system will before long be included in the Pleistocene, and that the latter will embrace all the glacial and interglacial stages. In a word, the term "Pleistocene" will eventually cover every accumulation formed during the great cycle of alternating climatic conditions. This being so, it will certainly include most of the deposits which in our and other glaciated regions are commonly termed *postglacial.*

For the present, however, let us consider the epoch of the "District Ice-Sheets and Mountain-Valley Glaciers," to be the closing phase of the Ice Age in Scotland, and proceed to inquire into the history revealed by the co-called "postglacial deposits" of our country. The most representative of these accumulations are our *raised beaches*, *estuarine* and *fluviatile terraces*, *lacustrine alluvia*, and *peat-mosses*.

RAISED BEACHES, ETC.

At least three well-marked raised beaches are visible at many places upon our coastlands. Of these the oldest occurs at a height of 100 to 135 feet above the present sea-level. There can be no doubt that this beach belongs to the true glacial series, and I only refer to it in this place because the phenomena connected with it are similar in many respects to those associated with some of the younger "postglacial" raised beaches. In the great valleys of the Forth and Tay, for example, it forms extensive terraces, which, as they are followed inland, gradually rise to higher and higher levels and merge into fluvio-glacial gravels, while these last even-

tually become associated with large terminal moraines. In short, the beach in question belongs to that stage of the Ice Age which I have termed the epoch of "District Ice-Sheets and Mountain-Valley Glaciers." During that stage our Highland fiords or sea lochs were invaded by great glaciers, and in their upper reaches we look in vain therefore for any trace of the 100 foot beach. At their lower ends, however, and on the open coast between adjacent sea lochs, the beach is frequently conspicuous. We can thus readily picture to ourselves the general aspect of Scotland at that time. The sea, with its arctic fauna, covered such of our present low grounds as do not exceed 130 feet in height or thereabout. Our estuaries were in winter largely frozen over, while in spring and early summer the ice, broken up into flows, often ran aground in shallow water—contorting and confusing the marine sediments in course of formation. Many erratics were by the same agency distributed over the floor of the sea. A continuous snow-cap covered the Highlands, from which large glaciers descended in many places to the coast, where they calved their icebergs—another fruitful source of erratics. In the Southern Uplands very considerable ice-streams likewise existed —some of which were of such extent that they escaped from their mountain valleys and deployed upon the low ground beyond, but none reached the seacoast. The central lowlands were at this time clothed with a truly arctic flora—among the characteristic plants being various northern willows (*Salix polaris*, *S. herbacea*, *S. reticulata*), dwarf birch (*Betula nana*), mountain avens (*Dryas octopetala*), etc. Associated with these arctic plants in the lacustrine deposits of the time *Apus glacialis* occurs in great abundance. As this phyllopod is now met with only in fresh-water lakes in Greenland and Spitzbergen, its presence in the ancient alluvia of central Scotland tells a plain tale.

All the deposits belonging to this stage, therefore—glacial, fluvio-glacial, lacustrine, and marine alike—we are justified in assigning to the Ice Age, and we may provisionally consider them as representing its closing phase.

The next succeeding raised beach is met with at a height of 45–50 feet above the present sea-level. Like its predecessor (the 100 foot beach), it is best developed in our great estuarine valleys—as

those of the Tay, the Forth, and the Clyde. Usually it assumes the form of well-marked terraces of gravel, sand, clay, and silt; but on the more open seacoasts it is not infrequently represented by ledges or benches cut in the solid rock. Most of the shells, etc., which it contains belong to still indigenous species.

Obviously a considerable interval of time separated the formation of these two raised beaches. Before the 45–50 foot beach began to be formed, the characteristic arctic species of the older beach had disappeared from our coasts. Further, there is evidence to show that after the 100 foot beach had been lifted out of the water, it was for a lengthy period subjected to severe erosion—more especially in our estuarine valleys. Moreover, it is quite clear that this erosion was effected by rain and rivers when the land stood at a relatively higher level than it does today, and at a date long prior to the formation of the 45–50 foot beach. In the valleys of the Tay and Earn, for example, the accumulations of the 100 foot beach have been extensively trenched and swept away from broad tracts, so that they now form terraces, the bluffs of which overlook the later carse deposits of the 45–50 foot beach. That the erosion referred to was not the work of the sea in which these younger estuarine beds were formed is proved by the simple fact that the latter do not rest directly upon the denuded deposits of the 100 foot beach. On the contrary, they are separated from these by a widespread sheet of peat, and this is directly underlain by river silt, clay, sand, and gravel.

It is clear, then, that the latest stage of the Glacial Period was accompanied or followed by a change in the relative level of land and sea. The sea retreated to a lower level than the present, while rivers plowed their way down through the deposits of the 100 foot beach, and in time formed broad alluvial flats which were overlooked on either side by the bluffs and terraces of the denuded shelly clays. By and by these younger "haugh-lands" were overspread with dense vegetation—the general character of which betokens a climate not less temperate than the present—the dominant species of trees being oak, alder, hazel, birch, etc. This old land-surface is now represented, as I have already mentioned, by a thick bed of peat—the rootlets of trees and other plants penetrating the underlying fluviatile deposits.

The deposits of the 45–50 foot beach immediately covering the peat are crowded, especially toward the base, with leaves, branches, and twigs of the trees just mentioned. When these estuarine accumulations are followed up the Tay valley, they gradually become more and more arenaceous, until eventually they merge into ordinary river alluvia—the materials of which become increasingly coarser as they approach the mountains.

It is worthy of note that the 45–50 foot beach often fails to appear at the heads of particular fiords in the west Highlands, although it may be well developed in their lower reaches. This is explained by supposing that glaciers may have occupied the upper ends of such fiords during the depression of the land—an inference much strengthened by the fact that at the head of Loch Torridon, where the beach in question is well seen, it is capped by conspicuous terminal moraines. This evidence, so far as it goes, leads to the conclusion that the more important phenomena characteristic of the 100 foot beach, were repeated—but on a smaller scale, and in a less pronounced degree—in the case of the 45–50 foot beach. In a word, we are forced to believe that during the formation of the latter snow-fields and glaciers existed in the Highlands.

The latest conspicuous raised beach is that occurring at an average level of 25 to 30 feet above the sea. The only shells it has yielded belong to still indigenous species. Nowhere, so far as known, do the deposits of this beach merge inland into fluvio-glacial gravels, nor does the beach appear to be anywhere associated with moraines. It frequently contains drifted stools and trunks of pine and other trees of large size. Now and again also we find it resting directly upon peat with trunks and stools of trees rooted in an underlying soil. It is often hard to say, however, whether these ancient land-surfaces may not sometimes be on the same geological horizon as the peat that underlies the deposits of the 45–50 foot beach.

PEAT-MOSSES

Postponing for the present any further remarks on the evidence supplied by our so-called postglacial raised beaches, I would shortly direct attention to certain other accumulations, which indubitably belong to later times than the closing stage of the Glacial Period,

as heretofore defined. I refer to our peat-mosses. Everyone is familiar with the fact that in and underneath these the relics of forest vegetation frequently occur. In many places throughout Scotland—as well in high grounds as in low grounds—the peat-mosses cover at least two ancient forest-beds. Typically the older forest-bed occurs at the base of the peat, while the younger tier of trees rests upon, and is covered by, a variable thickness of peat. In some bogs only a foot or two may separate the forest-beds, while elsewhere the intervening peat may attain a thickness of many yards. So far back as 1866 I endeavored to show that the very general occurrence of these phenomena was indicative of climatic changes.[1] The forest-beds, I maintained, were the products of relatively dry or continental conditions, while the intervening and overlying sheets of peat indicated colder and wetter conditions. I further pointed out that at the present time all our peat-mosses are more or less rapidly decaying, and being denuded by rain and wind—that, although peat is now forming here and there under favorable conditions, still that this is exceptional—the rate of growth being generally much exceeded by the rate of decay and removal. From this striking fact I inferred that the climate of Scotland has become drier since the formation of the peat overlying our upper forest-bed.

The earlier writers on the origin of the Scottish peat with its buried trees did not recognize the influence of climatic changes in the destruction of the old forests and their subsequent entombment in peat. According to them, the formation of the peat-bogs was due to the overthrow of the forests, chiefly by man's hand, but also perhaps by natural causes, such as tempestuous wind. The wholesale downfall of the forests, it was believed, had obstructed the natural drainage of the land, and thus induced marshy conditions favorable to the growth of sphagnum and its allies. More recently it has been suggested by some writers that in certain cases the drainage may have been interrupted by the heaping-up of banks of sand, clay, or other superficial accumulations, across broad valleys, whereby the forests over wide areas may have been destroyed by stagnant water, and thus have given rise to the formation of bogs. This is a somewhat far-fetched explanation. If it had any evidence

[1] *Transactions of the Royal Society of Edinburgh*, Vol. XXIV (1866), p. 363.

in its favor, this should not be hard to recognize. Where, one might ask, are those convenient bars or banks behind which the stagnant water is supposed to have accumulated?

That none of these explanations can be accepted as sufficient to account for the phenomena of our peat-bogs in general is shown by the mere fact that the buried forests are not confined to the peat of lowlying and gently undulating ground—to situations, namely, where the drainage might possibly have been disturbed by one or other of the causes suggested. On the contrary, they occur just as constantly in the peat covering mountain slopes and hilltops, where owing to the form of the ground, interruptions of the drainage could not possibly take place. Moreover, the nearly constant occurrence, throughout the peat of low grounds and high grounds alike, of at least two buried forests, obviously points to the operation of some widely acting recurrent cause.

Conclusions similar to mine were subsequently advocated by the late Professor Blytt, who, after a careful study of the peat-mosses of Norway, was convinced that these gave evidence of a well-marked alternation of wet and relatively dry climatic conditions having obtained after the low grounds of that country had been vacated by the great inland ice of the Glacial Period.[1] I need only add that the phenomena of successive "buried forests" have long been recognized almost everywhere in the peat-bogs of northern and northwest Europe. The occurrence of these trees, however, has been variously interpreted—some authors upholding views that are practically the same as those I ventured to set forth so many years ago, while others would attribute the origin of the peat-mosses to the overthrow of the trees by the various causes already referred to.

When we come to inquire into the relation of our Scottish peat-mosses to the glacial deposits, we have no difficulty in discovering that they are of later date than the epoch of "District Ice-Sheets and Mountain-Valley Glaciers." This is proved by the fact that the peat with its buried trees overspreads the fluvio-glacial gravels and moraines of that epoch. It would appear, then, that the oldest of our inland peat-mosses occupy the same geological horizon as

[1] *Essay on the Immigration of the Norwegian Flora during Alternating Rainy and Dry Periods*, 1876.

the peat and alluvia which have been referred to as underlying the deposits of the 45–50 foot beach, and which, as we have seen, rest upon the denuded deposits of the 100 foot beach. It is thus hardly possible to escape the conclusion that the ancient land-surface buried under the carse clays of the 45–50 foot beach is contemporaneous with the lower forest-bed of our inland peat-mosses. This, as I believe, gives us the key to the history of all the later climatic and geographical changes experienced by our country.

Summing up the evidence, we may recognize the following succession of events in the history of postglacial Scotland:

1. After the District Ice-Sheets and Mountain-Valley Glaciers had disappeared, the land gained in extent—the sea eventually retreating considerably beyond the present coast-line. The climate at the same time gradually improved, until genial conditions supervened and a strong forest growth covered the low grounds, and extended upward to elevations which trees in our country no longer attain. The relics of that great forest epoch we find in the Lower Forest Zone of our peat-mosses.

2. Next followed partial subsidence of the land, accompanied before long by a relapse to cold conditions. Snow-fields now reappeared, and considerable glaciers descended our mountain valleys and in some places reached the sea. The climate was wet and ungenial—the forests decayed, and bog-mosses gradually usurped their place. To this stage we assign the Lower Peat of our inland "mosses," and the 45–50 foot beach, as well as certain moraines and fluvio-glacial gravels.

3. The succeeding stage was characterized by re-elevation of the land, and the retreat of the sea beyond the present coast line. But the land was probably not so extensive as during the preceding forest epoch. This geographical change was marked by the disappearance of perennial snow and ice, and by a return to dry, genial conditions, apparently similar to those that formerly obtained. Forests again clothed the land—flourishing in many places over the surface of the now desiccated peat-mosses. This stage is represented by the Upper Forest Zone of our inland peat, and by the trees which occur under the deposits of the 25–30 foot beach.

4. Once more partial subsidence ensued, and the climate again

became somewhat cold and wet. Over wide areas the forests, as before, began to decay, and were eventually buried under the rapidly extending peat-mosses. We cannot actually demonstrate that snow-fields and glaciers reappeared at this stage. The latest beach we are able to correlate with the upper peat, but that beach is nowhere associated with moraines or glacial gravels. Nevertheless, we are not without evidence suggestive of the appearance at this time of inconsiderable glaciers among our highest mountains. The small glaciers referred to undoubtedly belong to a later date than the glaciers that dropped their moraines on the 45–50 foot beach. It is therefore not unreasonable to infer that our high-level corrie glaciers may have been contemporaneous with the formation of the 25–30 foot beach, and the Upper Peat of our inland "mosses." But the chief evidence of cold, wet conditions is unquestionably that furnished by the Upper Peat itself. It covers the Upper Forest Zone in precisely the same way as the Lower Peat overlies the Lower Forest Zone.

5. The final stage witnessed the retreat of the sea to its present level. The climate now became drier, and peat-mosses ceased to flourish as they had done in the immediately preceding epoch. Thus the final phase of postglacial history may be said to be characterized especially by the general decay and denudation of our peat-mosses—the vegetation growing upon which is almost invariably of a drier type than that found in the immediately underlying peat itself.

Did space permit, I might follow other lines of evidence, all leading to the conclusion that oscillations of climate marked the closing stages of Pleistocene times. For example, the phenomena presented by the alluvial terraces of our larger river valleys might be referred to. It would not be hard to show that, during the so-called "postglacial" period, our rivers have at some stages been most active as eroding agents, while at other stages their chief work has been the transportation and deposition of sediment. During genial epochs, when the land stood at a higher level than now, our rivers busied themselves especially in deepening and widening their courses—in trying to sweep away the glacial and fluvio-glacial detritus with which their valleys had been so largely choked. During cold, wet epochs the land was depressed below its present level,

and the larger rivers were then chiefly engaged in filling up the lower reaches of their valleys with the abundant sediment brought to them by their active tributaries. In a word, epochs of dominant erosion alternated with epochs of prevalent deposition.

I might also cite, in support of my general conclusions, certain facts relating to the present and past geographical distribution of animals and plants. The appearance, for example, in the North Atlantic, of isolated colonies of southern types of molluscs, surrounded on all sides by boreal and cold-temperate forms; and the occurrence now and again of similar no longer indigenous molluscs in the raised beaches of Nova Scotia, Greenland, Spitzbergen, and Scandinavia, are all alike strongly suggestive of warmer conditions having at a very recent period characterized the North Atlantic. Quite in keeping with these phenomena is the fact that the beaches in question are often crowded with southern types which, although still lingering on in these northern seas, do not now attain so large a size as their postglacial predecessors, while they are obviously much less abundant.

But these, and other lines of evidence, suggested especially by the geographical distribution of plants in temperate Europe, cannot be considered at present.

Although the proofs of alternating genial and ungenial climates supplied by our peat-mosses seem to me too strong to be resisted—fortified as they are by the evidence yielded by our raised beaches and recent morainic accumulations—I have yet long felt that they would probably be still further confirmed if our peat-mosses were subjected to a thorough examination by competent botanists. I could not doubt that a careful study of the constituents of our peat-mosses would throw light on the changing character of the climate during the period of their accumulation. It was obvious, even to me who am no expert in botany, that peat was composed of other plants than the bog-moss—in many sections I could see what appeared to be a succession of layers made up of the remains of different kinds of plants. And often have I regretted the botanical ignorance which forbade any attempt on my part to interpret what that succession meant—that it had some interesting tale to tell I did not doubt. Fortunately the work of interpretation has at last been taken up by an accomplished botanist. Mr. Francis J. Lewis, of the University

of Liverpool, has during the last few years subjected our peat-mosses to a careful examination, with results that are sufficiently striking. His work is not yet completed, but he has already studied the peat of our Southern Uplands, and carried on similar researches throughout wide areas in the Highlands. The data now collected have convinced him that a definite succession of plants everywhere characterizes the Scottish peat: and he confirms the view of alternating climatic conditions which I formulated forty years ago.

The Southern Uplands is the general term applied to that belt of hilly and mountainous country which extends from the coasts of South Ayrshire and Wigtonshire to the high grounds that terminate on the east coast between the valleys of the Tweed and the Tyne. Throughout this broad tract peat-mosses abound—large areas of the higher grounds being of a dominantly moorland character. Nowhere are the peat-mosses better developed than in the mountainous district of Merrick, in Galloway, and in the lofty region in which the river Tweed takes its rise. To these two typical areas Mr. Lewis has devoted special attention, and the results of his observations have already been published.[1] In both districts the peat-mosses bear the same relation to the glacial and fluvio-glacial deposits —they everywhere overlie the moraines and morainic detritus of our "District Ice-Sheets and Mountain-Valley Glaciers."

The first well-marked zone at the base of the peat in the Southern Uplands is a solid layer of the remains of white birch (*Betula alba*), mixed with such plants as heather (*Calluna vulgaris*), and willow (*Salix repens*). Mr. Lewis thinks it is hardly possible that this zone represents the primitive vegetation which covered the Uplands immediately after the disappearance of glacial conditions. The first-comers would naturally be arctic types, the preservation of which, however, would entirely depend upon climatic and local conditions. In the Merrick District Mr. Lewis observed that in many places a thin layer of peat occurred immediately underneath the birch zone, but unfortunately the material was in too decomposed a condition to allow of the identification of any particular

[1] "The Plant Remains in the Scottish Peat-Mosses; Part I: The Scottish Southern Uplands," *Transactions of the Royal Society of Edinburgh*, Vol. XLI (1905), p. 699.

plants. It is quite possible, he thinks, that the structureless peat referred to may represent the primitive vegetation of the district.[1] I may remark that similar structureless peat not infrequently underlies the lower forest-zone in the peat-bogs of Scandinavia.

The birch zone is directly overlain by a thick stratum of peat, composed entirely of bog-moss (sphagnum). This succession is constantly repeated throughout the Southern Uplands—alike in the peat at the bottoms of valleys, and in that upon steep hillsides and flat hilltops. The sphagnum bed thus bears witness to a general increase of precipitation—it represents, in short, a change from birch-forest conditions to wet moorland.

As successive layers of the peat are followed upward, Mr. Lewis finds that the bog-moss gradually gives place to cotton-grass (*Eriophorum vaginatum*) and rushes (*Scirpus*). After these plants had flourished for some considerable time, a decided change of climate supervened. In the Merrick district the cotton-grass peat is covered by a dense layer of the stems of crowberry (*Empetrum nigrum*), and two characteristic Arctic willows (*Salix herbacea* and *S. reticulata*). The same zone is represented in the peat of Tweedsmuir by the crowberry, and the creeping azalea (*Loiseleuria procumbens*)—the latter being a typical Arctic form. The constant appearance of this remarkable zone throughout the Southern Uplands can have only one meaning—it points unmistakably to a decided decrease of temperature. It indicates a stage during which the valleys of Southern Scotland were characterized by a climate as rigorous as that now experienced on the summits of our loftiest mountains.

The gradual dying-away of this cold epoch, and the reappearance of forest vegetation, are, according to Mr. Lewis, faithfully chronicled by the peat. The crowberry, the arctic willows, and the creeping azalea give place above to cotton-grass, and this in its turn to bog-moss or sphagnum—a succession common to the peat throughout the Southern Uplands. Eventually the wet moorland conditions indicated by the sphagnum peat passed away; the bogs dried up, and were invaded by trees—by forests of pine in the Merrick district and forests of white birch in Tweedsmuir.

[1] The evidence wanting at the base of the peat is supplied by the lacustrine alluvia of the central Lowlands already referred to. See p. 5.

Finally, the conditions again became adverse to forest growth, and the trees of this Upper Zone were gradually buried under a stratum of peat, consisting chiefly of rushes, bog-moss, and cotton-grass.

In comparing the peat-mosses of the Southern Uplands with those of the Northern Highlands, Mr. Lewis finds that the latter begin their history at a later stage than the former. At high levels in the highlands none of the beds underlying the zone of arctic plants in the Southern Uplands puts in an appearance. The reason for this is obvious. The recurrence of cold conditions, indicated by the arctic plants of the Southern Uplands, was more strongly marked in the Northern Highlands. In those elevated regions considerable snow-fields and glaciers reappeared, and all peat-beds representing the lower forest zone of southern Scotland were swept away. As these glaciers in the north began to retreat, a tundra vegetation invaded the formerly glaciated tracts. Arctic willows (*Salix reticulata and S. herbacea*) at first were dominant forms, but these gradually gave place to subarctic types (*Salix Arbuscula*, *Betula nana*, *Empetrum nigrum*, etc.). By and by this subarctic brush-wood disappeared, and was succeeded by a close growth of cotton-grass and bog-moss, interspersed with some scraggy birch. That the climate eventually became more humid is suggested by the fact that the birch in its turn vanished, and sphagnum alone continued for a long time to occupy the ground. These wet moorland conditions next passed away—the thick sphagnum peat drying up, and eventually supporting a forest of large pines, with an undergrowth of common heather. The great pine forests of this Upper Zone, it may be mentioned, flourished at elevations between 2,000 and 3,000 feet above the present sea-level. Finally they decayed, and were gradually buried under peat consisting chiefly of bog-moss and rushes.

My limits will not allow me to enter into other interesting evidence adduced by Mr. Lewis. I may just mention, however, that he finds everywhere evidence that existing conditions no longer favor the general growth of peat. On hilltop, hillside, and in upland valleys alike, the peat, he says, is almost without exception being rapidly wasted away. The vegetation at present covering the peat

is nearly always of a drier type than that occurring at slightly greater depths—a fact, he remarks, not without its bearing upon the present denuded state of the "mosses."

From this brief and imperfect summary of the results obtained by Mr. Lewis, it will be admitted that the geological evidence of climatic changes in so-called postglacial times has been decidedly strengthened. It is most satisfactory to learn that a definite zone of arctic plants is intercalated in the peat separating the lower from the upper forest-bed. The occurrence of these plants midway between the two forest zones, and the succession of plant remains in the peat-beds immediately overlying and underlying the zone of arctic plants, all point to a gradual change from dry forest to wet moorland, and from wet moorland to cold tundra, and again from cold tundra to wet moorland, and from the latter to dry forest.

In the peat overlying the Upper Forest zone no trace of arctic plants has been met with. Mr. Lewis thinks it is possible, however, that these may yet be detected in those high-level peat-mosses which were formed contemporaneously with the moraines of the youngest corrie glaciers. It may be so; but I doubt whether the wet and relatively cold conditions indicated by the high-level corrie moraines, and the peat which covers the Upper Forest zone, were sufficiently pronounced to induce any conspicuous modification of the flora. All we can infer is that the climate was inclement enough to check forest growth, and to favor the increase of the bog-moss and its allies. The temperature, however, need not have differed greatly from the present. Only a slight lowering of the present temperature, with a corresponding small increase of precipitation, would cover our highest mountains with perennial snow-caps and reproduce their corrie glaciers.

The various superficial accumulations which have formed the subject of this address are usually classified as *postglacial*. But as they obviously carry on the story revealed by the older glacial and interglacial deposits, they ought not, in my opinion, to be separated from these. They form the concluding chapters of the history of Pleistocene times. That great cycle of climatic oscillations which commenced before the close of the Pliocene period and reached down to the dawn of the present, forms one of the most remarkable

episodes of the past, and ought to be recognized in our classification as constituting a distinct division of time. By refusing to do so, and including the Weybourn Crag, the Cromer Forest bed, etc., in the Pliocene, we cut off from the Pleistocene the earliest recognizable glacial and interglacial epochs; and we similarly separate from the great cycle its closing phases when we classify these as postglacial. So far as temperate Europe is concerned, it is only the *present* which is postglacial.

How many climatic oscillations may eventually be included in the so-called glacial period we cannot tell. If we confine attention to such glacial and interglacial stages as are actually known, it would seem that the climax of each phase was attained in early Pleistocene times. After that climax was passed, each successive glacial and interglacial epoch declined in importance—the contrast between the two phases gradually became less pronounced. Interglacial conditions reached their maximum with the advent in our latitude of the great southern pachyderms—hippopotamus, elephant, and others—and died out with the Upper Forest Zone of our peat-mosses. Glacial conditions culminated with the appearance of the enormous ice-sheet of the Saxonian stage, and finally disappeared, so far as Scotland was concerned, with the small isolated snow-fields and diminutive glaciers of our loftiest Highland mountains.